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Reliability indexes for offshore wind power production under extreme wind conditions

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Abstract

Reliability of offshore wind production under extreme wind conditions was investigated in this paper. The wind power variability from several offshore wind farms in Western Denmark were simulated using the Correlated Wind model developed at Risø. A total of 25 annual wind power time series for six large offshore wind farms were used in the analysis. Two storm control strategies were used. The analysis involved several aspects inspired from reliability studies. The reliability aspects investigated are storm events occurrences and durations, storm control strategy impact on the capacity factor (lost production), ramp rates and reserve requirements.

CorWind Simulations Software

CorWind can simulate wind power time series over a large area such as a power system region and in time scales where the wind turbines can be represented by simple steady state power curves, i.e. typically greater than a few seconds.

CorWind uses reanalysis data from a climate model to provide the mean wind flow over a large region, and then adds a stochastic contribution

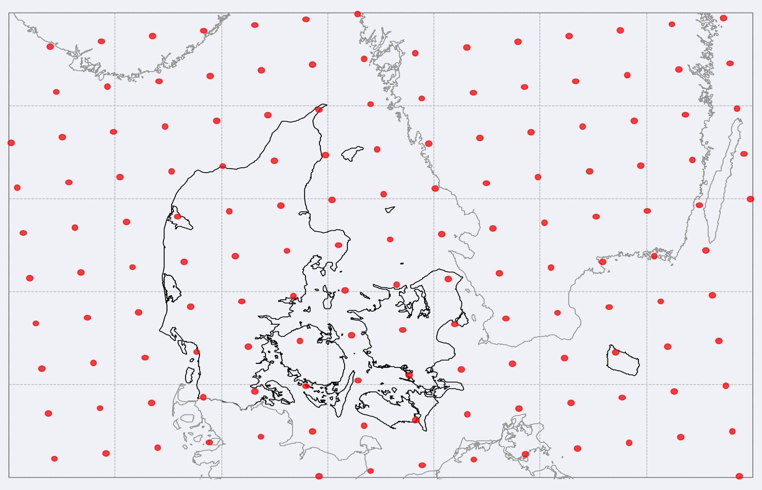

Fig. 1 Resolution of applied climate model data

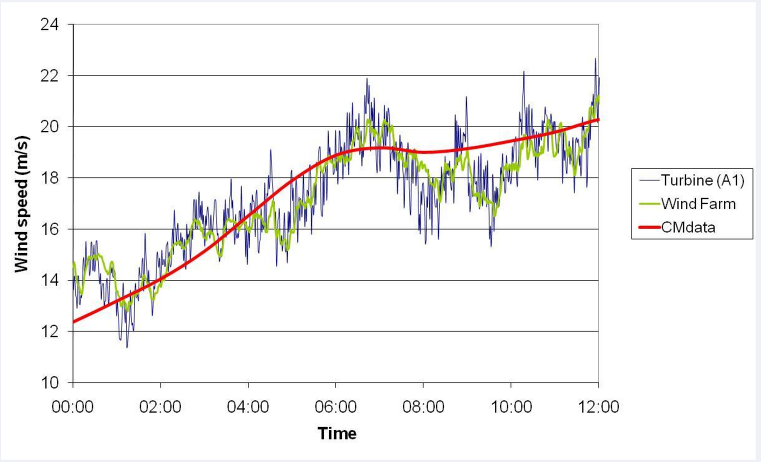

Fig. 2 Comparison of variability

Wind Turbine Control Under Extreme Wind

In order to protect the mechanical parts during extreme winds the wind turbine stops. When the wind speed average over a certain period of time (usually 10 min) exceeds a certain value (typically 25 m/s for modern wind turbines), then the wind turbine stops. This is illustrated by HST in Figure 3. Another way of dealing with operation during extreme winds is the one called SST in Figure 3. This strategy prevents sudden shuts down, by starting to reduce the wind turbine power output at a certain wind speed average value. If the wind speed keeps increasing, the power production will be further reduced until, eventually, it will stop.

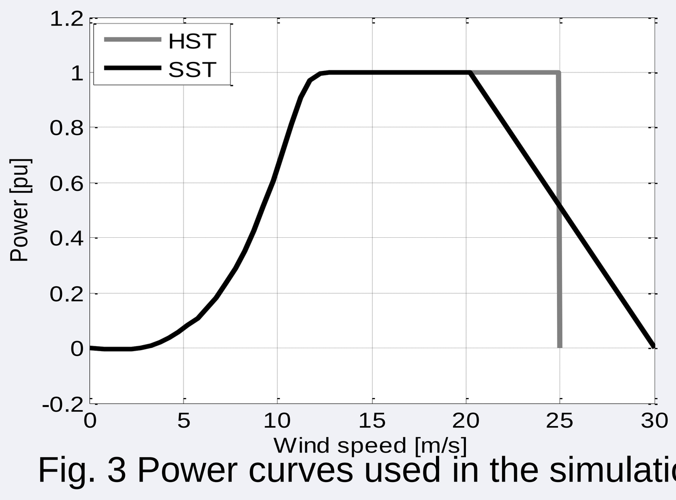

Fig. 3 Power curves used in the simulations

Simulation Setup I

All wind farms are simulated for 5 years of Reanalysis data, 1999 – 2003. The time step of the simulation is selected to 1 minute. The stochastic part is simulated with a period time of 1 day. This is a compromise between computer simulation time and simulation accuracy. Longer period times are possible, but it would require longer computer simulation time, and yet not add variability because the stochastic part includes variability faster than one day. To ensure that the stochastic randomness is still properly represented, each year was simulated with 5 different random seeds for the stochastic part. Thus, a total of 25 years, i.e. 5 years x 5 seeds, of simulation time series are used for the analysis.

The idea is now to analyse the reliability of the individual wind farms during extreme winds events (storms) as well as to compare two scenarios:

1. The concentrated scenario: Horns Rev and Horns Rev 2 are supplemented with 2 new wind farms Horns Rev A and Horns Rev B;

2. The spread scenario: Horns Rev and Horns Rev 2 are supplemented with 2 new wind farms Anholt O and Anholt P.

Simulation Setup II

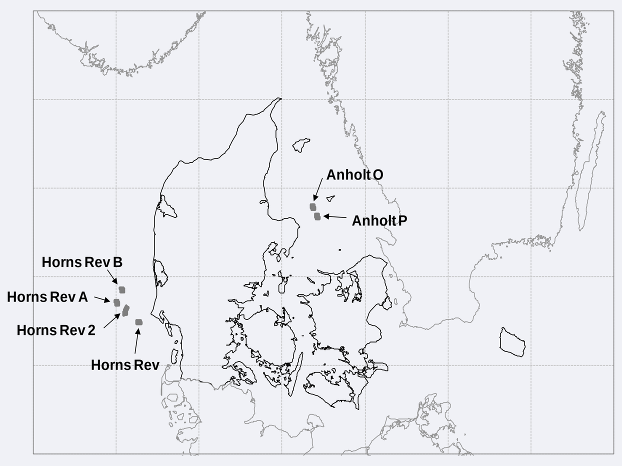

Fig. 4 Simulated wind farms

Table 1 Data for the 6 simulated wind farms

Name	Symbol	Wind turbine power	Total power	Annual mean wind speed
Horns Rev	HR1	80 × 2.0 MW	160 MW	9.6 m/s*)
Horns Rev 2	HR2	91 × 2.3 MW	209 MW	10.4 m/s*)
Horns Rev A	HRA	40 × 5.0 MW	200 MW	10.6 m/s*)
Horns Rev B	HRB	40 × 5.0 MW	200 MW	10.5 m/s*)
Anholt O	DAO	40 × 5.0 MW	200 MW	9.0 m/s*)
Anholt P	DAP	40 × 5.0 MW	200 MW	9.0 m/s*)

Results

Frequency of occurrence

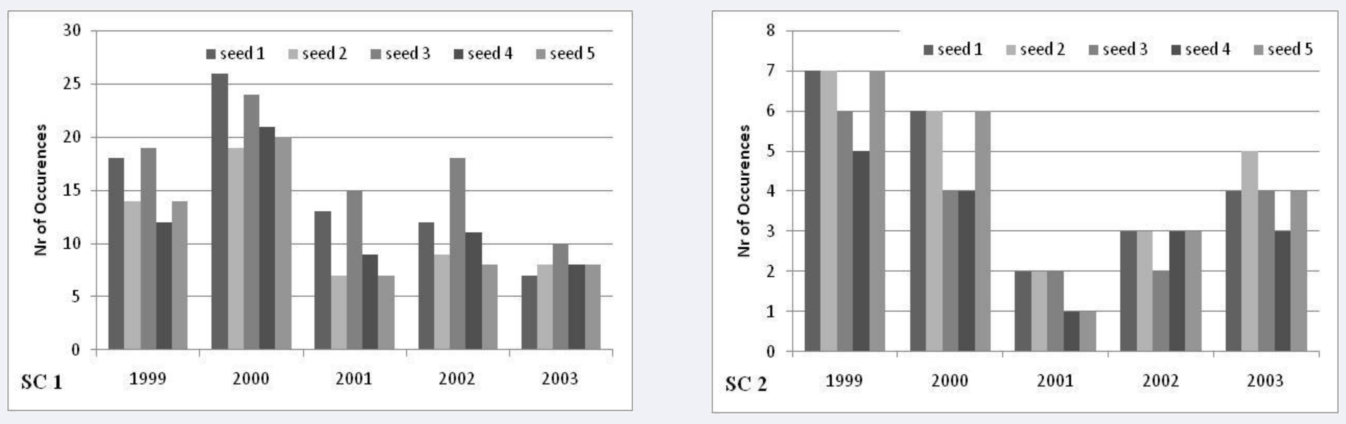

Fig. 5 Storm events occurrences for each scenario

Lost Energy

Table 2 Data for the 6 simulated wind farms

Name	HR1	HR2	HRA	HRB	DAO	DAP
Capacity factor difference %	0,25	0,37	0,39	0,38	0,13	0,12
Equivalent full load hours	21,65	32,80	34,26	33,04	11,02	10,81

Ramp Rates

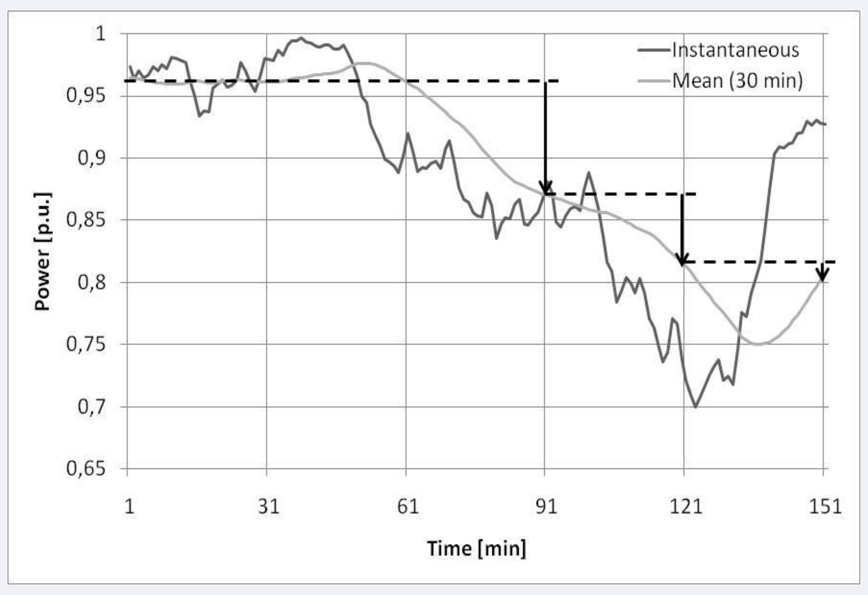

Fig. 6 Ramp rate definition

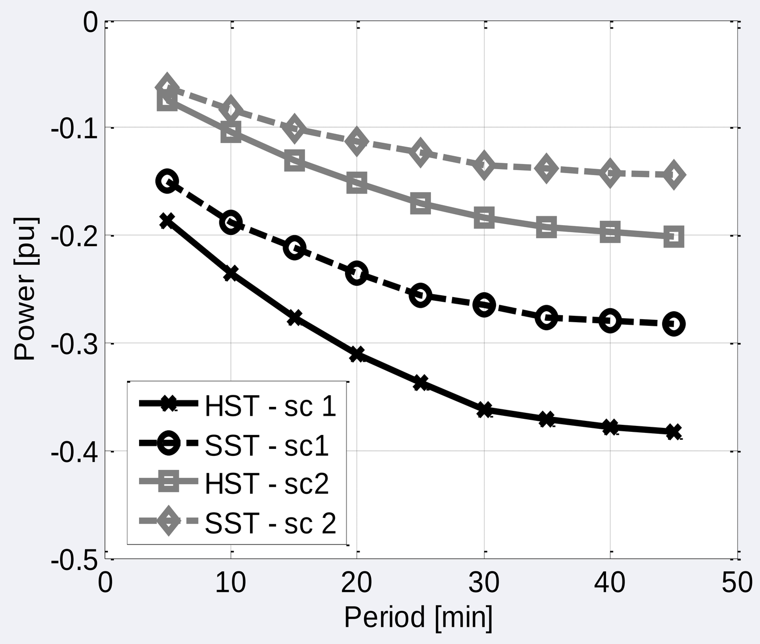

Fig. 7 1% fractile versus time windows

Reserve Requirements

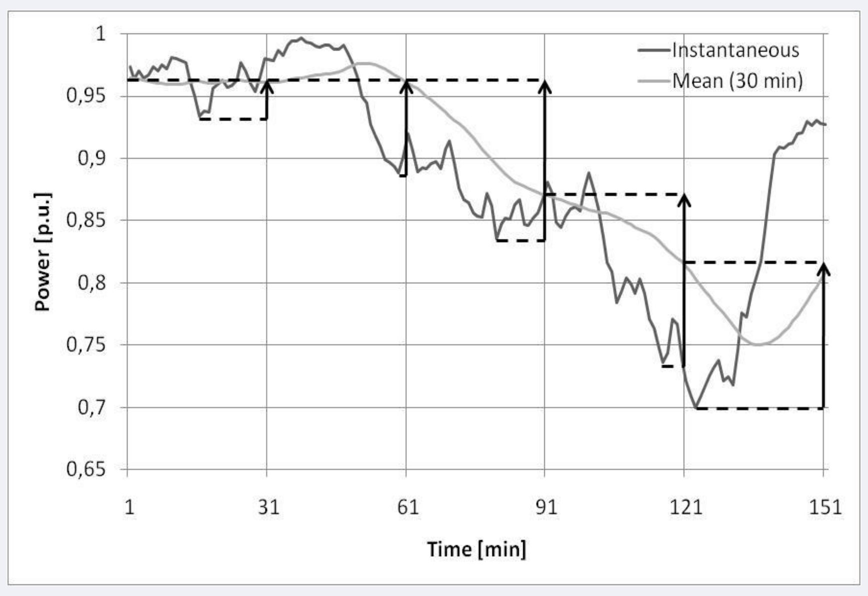

Fig. 8 Reserve requirement definition

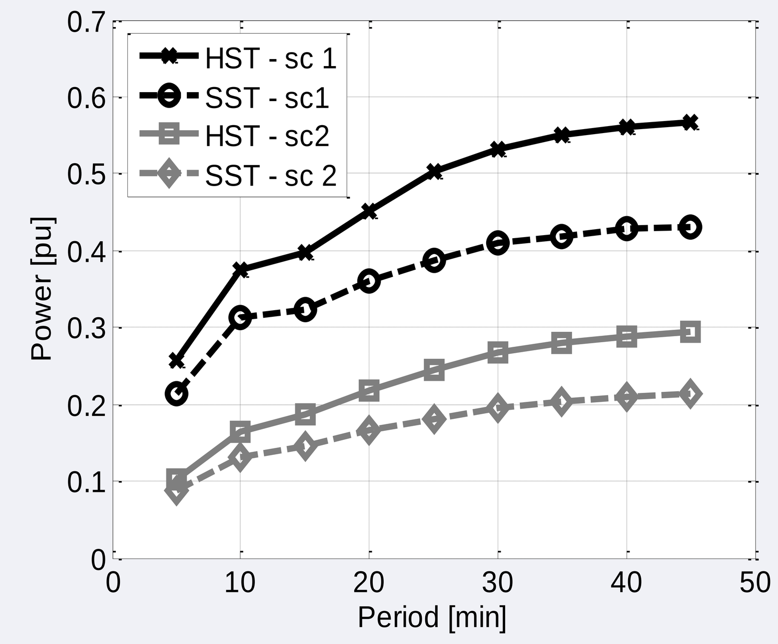

Fig. 9 99% fractile versus time windows

Conclusions

Operational reliability offshore wind power production under extreme winds is important. Indexes for operational .reliability of offshore production under extreme winds should be defined.

Control strategies play a crucial role in increasing the reliability of offshore wind farms power production under extreme wind conditions.

Availability of wind power production at power region level can be improved by proper wind farm location selection